groundwater elevation occurring in wells at lower topography is possible due to the effects of bank storage from Lauderick Creek (Fetter, 1988). Lauderick Creek, which normally receives discharge from the surficial aquifer, is temporarily storing water in the surficial aquifer to recover from the multiple precipitation events. The rise of elevation within these selected wells indicates a direct hydraulic connection between the surficial aquifer and Lauderick Creek. Sections of the surficial aquifer affected by local tides is dependant on (1) the degree of hydraulic connection with the creeks and river or (2) pressures created by the increase in weight on sediment overlying the surficial aquifer.

Figure 3-12 illustrates a thermal imagery map of the Northern Bush River Area. This map shows temperature gradient changes in the surface water for Lauderick Creek, Kings Creek, and the Bush River (U.S. Geological Survey, 1993). These temperature gradients indicate warmer groundwater grading into cooler surface water. Warmer temperature gradient colors (red and orange) within surface water bodies suggest that surficial aquifer groundwater is hydraulically connected to the surface water through concentrated discharge (U.S. Geological Survey, 1993). Colors indicating concentrated discharge are along the northern shoreline and portions of the southwestern shoreline of the Northern Bush River Area. Temperature gradients along the northern and southwestern shorelines of the tributaries also show a different coloration. The blues, greens, and scattered yellows indicate diffuse discharge of surficial aquifer groundwater. This slower rate of discharge is directly adjacent to the shorelines of Lauderick Creek and Kings Creek. Temperature gradients further offshore suggest that a more concentrated discharge of surficial aquifer groundwater is occurring farther out into the creeks and the Bush River.

Slug tests provide data for estimating the aquifer's hydraulic conductivity (K) at each well point. For the purpose of slug test methodology, each well is classified as existing in unconfined or confined aquifer conditions based on borehole data. To determine the hydraulic conductivity for wells in unconfined aquifer conditions, geologists performed rising head slug tests and Bouwer-Rice method calculations. To determine hydraulic conductivity for wells in confined aquifer conditions, geologists performed falling head slug tests and Copper et al. method calculations yielding the aquifer transmissivity. Hydraulic conductivity (K) for confined aquifer conditions is calculated by dividing the transmissivity (T) by the saturated thickness (b) (Fetter 1988 and Freeze and Cherry, 1979).

Slug test data are available for all 19 surficial aquifer wells. Table 3-4 summarizes the hydraulic conductivity (permeability) and transmissivity values along with the confined or unconfined classification. The estimated aquifer saturated thickness is dependant on the screen interval placement of the well. The hydraulic conductivity (permeability) values ranged from 0.004 to 239 feet per day within the surficial aquifer. Based on the well hydraulic data, the average hydraulic

Flightline 1a Thermal Imagery

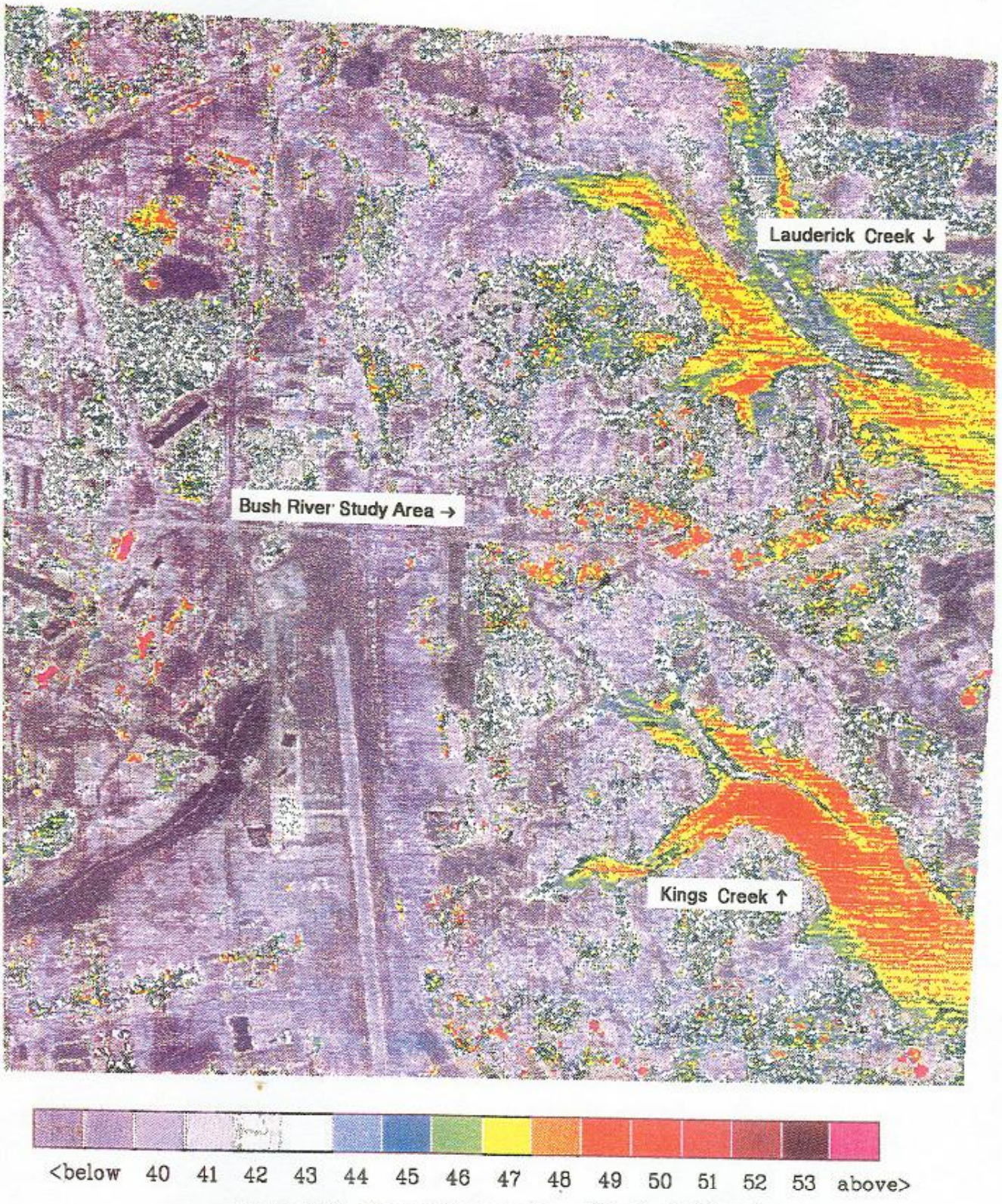

Figure 3-12. Thermal Imagery Map of the Bush River Area

Table 3-4. Well Hydraulic Data

Well	Transmissivity (feet^2/day)	Transmissivity (gallons/day/foot)	Hydraulic Conductivity (feet/day)	Hydraulic Conductivity (gallons/day/foot^2)	Total Dissolved Solids (TDS) Results (mg/L)[a]
Cluster 7 (Boat Club Fill Sites) Surficial Aquifer *					
WBR-11	184	1,376	13	97	120
WBR-12	202	1,511	15	112	114
WBR-13	19	142	6	45	265
WBR-14	35	262	2	15	61
Average	110	823	9	67	140
Cluster 35 (DPW Storage Areas) Surficial Aquifer*					
WBR-76	477	3,568	32	239	104
WBR-81	20	150	9	67	89
WBR-82	8	60	1	7	3,080
WBR-84	18	135	2	15	108
WBR-86	21	157	4	30	71
WBR-87	2	15	0.3	2	80
WBR-88	546	4,084	31	232	116
Average	156	1,167	11	85	521
Cluster 36 (Warehouse Sites) Surficial Aquifer*					
WBR-70	13	97	5	37	170
WBR-74	69	516	11	82	210
WBR-75	13	97	2	15	181
WBR-77	7	52	0.7	5	215
WBR-78	15	112	2	15	275
WBR-79	3	22	0.4	3	194
WBR-80	1	7	0.3	2	202
Average	17	129	3	23	207
Northern Bush River Surficial Aquifer Using Values from Above Wells*					
Average	92	687	8	57	314

* Estimated aquifer hydraulic data based on slug test results at individual monitoring wells.
a Highest validated result from sampling rounds.
mg/L milligrams per Liter.
7.48 gallons = 1 feet^3
Wells WBR-11, -12, -15, -74, -76, -82, -83, -84, -86, -87, and –88 classified as unconfined.
Wells WBR-13, -70, -75, -77, -78, -79, -80, and –81 classified as confined.
Well WBR-83 results (hydraulic conductivity = 0.004 feet per day and transmissivity = 0.02 feet^2 per day) not included.

conductivity for the surficial aquifer is 57 feet per day. The well hydraulic values give a representation in the variability of hydraulic conductivity throughout portions of the aquifer.

3.5.4 Groundwater and Surface Water Quality

Two rounds of surficial aquifer groundwater quality parameters are available for each of the 19 surficial aquifer monitoring wells. Two rounds of surface water quality parameters are available for each of the 13 surface water samples. The monitored parameters include temperature, pH, specific conductivity, salinity, dissolved oxygen, turbidity, and oxygen reduction potential. An average for each of the groundwater parameters is calculated by using the last set of parameters taken before sampling and the ending set of parameters taken after sampling. The surface water parameters are only recorded once before sampling. These seven parameters are basic indicators of the surficial aquifer and surface water body environments, which can be useful in predicting and/or explaining the persistence of groundwater and surface water contamination. Table 3-5 summarizes the averages of the parameters for each well and their corresponding date taken during the first round of groundwater sampling. Table 3-6 summarizes the averages of the same parameters at each well and their corresponding date taken for the second round of groundwater sampling. Tables 3-7 and 3-8 list the seven recorded parameters for each surface water sample and their corresponding dates taken for both sampling rounds, respectively. The samples were collected during different seasons under separate cluster sampling events (see Table 2-3). Therefore, only limited correlations can be made between the surficial aquifer and surface water. The groundwater is slightly acidic, with an average salinity of 0.2 percent, while the surface water is neutral with an average salinity of 1.5 percent.

3.5.5 Groundwater Usage and Aquifer Classification

Groundwater is currently not used as a drinking water source in the Edgewood Area of APG. Drinking water is supplied to area buildings from an Army-owned supply plant. The nearest domestic wells obtaining groundwater for potential drinking water usage are located on Nuttal Avenue in the town of Edgewood, approximately one mile northwest of the Northern Bush River Area (Advanced Sciences, Inc., 1994). Seven identified domestic wells obtain water from the surficial aquifer, located approximately three watersheds away from Northern Bush River. Three identified domestic wells obtain water from a deeper, confined aquifer that is hydrogeologically unrelated to the surficial aquifer in Northern Bush River (EA Engineering, Science, and Technology, 1996a). Therefore, these domestic wells cannot be adversely influenced by groundwater contamination in the Northern Bush River Area.

Table 3-5. Round 1 Surficial Aquifer Groundwater Quality Parameters

Well Number	Date (month/year)	Temp. (°C)	pH	Cond. (mS/cm)	Salinity (%)	DO (mg/L)	Turbidity (NTU)	ORP (mV)
WBR-11	May 1996	16.1	4.50	0.190	0.1	0.76	6.46	206
WBR-12	May 1996	17.0	5.20	0.188	0.1	0.07	3.97	-19
WBR-13	May 1996	14.6	5.86	0.474	0.2	0.33	0.31	243
WBR-15	May 1996	16.0	6.09	0.178	0.1	0.21	8.22	-34
WBR-70	February 1995	12.7	6.39	0.432	NR	0.16	5.20	-126
WBR-74	February 1995	17.3	4.83	567	NR	1.50	17.21	104
WBR-75	February 1995	14.6	5.89	0.326	NR	0.15	10.75	-102
WBR-76	January 1995	15.6	6.07	0.125	NR	0.18	16.80	-9
WBR-77	February 1995	13.8	6.37	0.432	NR	0.16	5.20	-126
WBR-78	February 1995	12.5	6.27	567	NR	0.14	0.14	-92
WBR-79	February 1995	8.5	5.98	322	NR	1.5	17.21	104
WBR-80	February 1995	14.2	5.62	291	NR	0.26	3.29	23
WBR-81	January 1995	17.0	5.16	148	NR	151	2.01	168
WBR-82	January 1995	13.8	4.29	5.21	NR	1.56	3.00	362
WBR-83[1]	January 1995	15.2	4.95	0.282	NR	4.68	2.70	261
WBR-84	January 1995	14.6	5.55	0.145	NR	1.80	22.40	148
WBR-86	January 1995	17.2	4.49	0.000	NR	1.66	3.50	332
WBR-87	January 1995	13.6	5.41	37	0.5	3.49	10.26	259
WBR-88	January 1995	13.5	5.24	0.136	NR	5.78	5.3	333

[1] Post sampling parameters only

NR = Parameter was not recorded
DO = Dissolved oxygen
ORP = Oxidation reduction potential
mg/L = milligram per liter
mV = millivolts
Cond. = Conductivity
mS/cm = millisiemen per centimeter
Temp. = Temperature
NTU = Nephelometric Turbidity Unit

Table 3-6. Round 2 Surficial Aquifer Groundwater Quality Parameters

Well Number	Date (month/year)	Temp. (°C)	pH	Cond. (mS/cm)	Salinity (%)	DO (mg/L)	Turbidity (NTU)	ORP (mV)
WBR-11	August 1996	19.8	5.30	0.180	0.1	1.75	5.80	313
WBR-12	August 1996	22.5	6.57	0.186	0.1	1.22	6.30	24
WBR-13	August 1996	22.8	6.92	0.476	0.3	0.34	0.70	153
WBR-15	August 1996	20.0	6.86	0.163	0.1	0.26	22.2	-47
WBR-70	June 1995	19.2	6.14	0.300	0.1	0.09	22.30	-105
WBR-74	June 1995	18.9	4.64	0.295	0.1	0.73	8.02	268
WBR-75	June 1995	17.0	5.77	0.354	0.2	0.16	18.00	-22
WBR-76	May 1995	15.6	5.89	0.137	0.1	0.21	6.71	62
WBR-77	June 1995	20.7	6.43	0.384	0.2	0.11	2.65	-148
WBR-78	June 1995	20.2	6.58	0.524	0.2	0.25	2.45[1]	66
WBR-79[1]	June 1995	22.5	5.65	0.308	0.1	0.14	20.40	-42
WBR-80	June 1995	17.3	5.52	0.260	0.1	0.16	8.10	34
WBR-81	May 1995	13.4	5.42	0.145	0.1	0.65	2.04	249
WBR-82	May 1994	18.1	4.30	6.300	4.0	1.26	2.84	274
WBR-83[2]	May 1994	17.6	4.99	0.274	0.1	1.05	3.23	247
WBR-84	May 1994	16.5	5.57	0.117	0.1	1.73	9.01	220
WBR-86	May 1994	14.4	4.95	0.099	0.1	3.22	2.57	338
WBR-87	May 1994	13.6	5.1	0.039	0.0	3.65	5.61	313
WBR-88	May 1994	13.8	4.98	0.126	0.1	7.49	5.77	356

1 Pre-sampling parameters only

NR = Parameter was not recorded
DO = Dissolved oxygen
ORP = Oxidation reduction potential

2 Post sampling parameters only

mg/L = milligram per liter
mV = millivolts
Cond. = Conductivity
mS/cm = millisiemen per centimeter
Temp. = Temperature
NTU = Nephelometric Turbidity Unit

Table 3-7. Round 1 Surface Water Quality Parameters

Well Number	Date (month/year)	Temp. (°C)	pH	Cond. (mS/cm)	Salinity (%)	DO (mg/L)	Turbidity (NTU)	ORP (mV)
C07-SW-01	May 1996	24.0	8.83	3.20	0.2	8.93	18.16	204
C07-SW-02	May 1996	25.6	8.60	3.22	0.2	8.65	19.30	162
C07-SW-03	May 1996	25.7	7.68	3.24	0.2	9.62	26.0	195
C07-SW-04	May 1996	27.5	8.14	3.32	0.2	9.46	19.86	233
C07-SW-05	May 1996	26.1	8.11	3.16	0.2	9.01	16.90	215
C36-SW-01	March 1995	15.8	7.20	2.30	1.5	8.84	35	190
C36-SW-02	March 1995	12.2	5.75	2.22	1.5	6.99	50	201
C36-SW-03	March 1995	15.4	6.92	2.34	1.5	8.30	52	214
C36-SW-04	March 1995	16.4	5.91	2.07	1.3	9.09	61	202
C35-SW-01	January 1995	6.4	6.76	1.522	NR	9.78	27	94
C35-SW-02	January 1995	1.0	6.8	1.360	NR	11.40	7	240
C35-SW-03	January 1994	1.2	6.80	1.252	NR	11.83	40	127
C35-SW-04	January 1994	3.0	6.62	0.946	NR	11.09	33	165

NR = Parameter was not recorded
DO = Dissolved oxygen
ORP = Oxidation reduction potential
mg/L = milligram per liter
mV = millivolts
Cond. = Conductivity
mS/cm = millisiemen per centimeter
Temp = Temperature
NTU = Nephelometric Turbidity Unit

Table 3-8. Round 2 Surface Water Quality Parameters

Well Number	Date (month/year)	Temp. (°C)	pH	Cond. (mS/cm)	Salinity (%)	DO (mg/L)	Turbidity (NTU)	ORP (mV)
C07-SW-01	August 1995	28.9	NR	5.52	0.3	11.94	40.6	83
C07-SW-02	August 1995	28.8	NR	5.34	0.3	11.88	33.4	80
C07-SW-03	August 1995	28.3	NR	5.00	0.2	11.42	39.1	85
C07-SW-04	August 1995	26.0	NR	4.64	0.2	8.05	50.1	162
C07-SW-05	August 1995	23.4	NR	4.52	0.2	7.56	109	214
C36-SW-01	June 1995	25.0	6.23	3.440	1.8	4.21	35	234
C36-SW-02	June 1995	23.3	5.72	3.190	1.7	2.87	174	243
C36-SW-03	May 1995	23.8	5.77	3.250	1.8	2.42	156	241
C36-SW-04	June 1995	24.3	6.61	1.700	1.7	5.79	44	396
C35-SW-01	May 1995	15.8	6.35	2.02	1.3	7.18	29	317
C35-SW-02	May 1995	16.3	7.64	2.11	1.3	7.90	30	340
C35-SW-03	May 1994	18.6	7.39	2.25	1.3	9.91	24	298
C35-SW-04	May 1994	NR	NR	NR	NR	NR	NR	NR

NR = Parameter was not recorded
DO = Dissolved oxygen
ORP = Oxidation reduction potential
mg/L = milligram per liter
mV = millivolts
Cond. = Conductivity
mS/cm = millisiemen per centimeter
Temp. = Temperature
NTU = Nephelometric Turbidity Unit

Based on Code of Maryland Annotated Regulations (COMAR) 26.08.02.09 and the USEPA Region III classification, the Northern Bush River surficial aquifer conforms to the Type IIB and USEPA Class IIB aquifer classification. Table 3-9 outlines aquifer types identified by the COMAR. Table 3-4 listed transmissivity and hydraulic conductivity (permeability) values from slug tests at the surficial aquifer monitoring wells. Both the estimated transmissivity values (averaging 687 gallons/day/foot) and hydraulic conductivity (permeability) values (averaging 57 gallons/day/foot^2) are representative of the outlined criteria for classification as a Type IIB or Class IIB aquifer. In addition, total dissolved solids average 314 milligrams per Liter (mg/L). Slug test data calculations from the well screen intervals result in transmissivity and hydraulic conductivity (permeability) values that are only representative of a small area around each well (Driscoll, 1989 and EA Engineering, Science, and Technology, Inc., 1996b). Because of the potential for underestimating the hydraulic parameters, the Northern Bush River surficial aquifer qualifies as a potential source of drinking water (i.e., Type IIB or Class IIB aquifer).

3.6 Human Population and Land Use

Aberdeen Proving Ground lies adjacent to the Chesapeake Bay, 20 miles northeast of Baltimore, Maryland, with most of the Installation lying within Harford County. Major rail and road corridors run through southern Harford County. Major road corridors include U.S. Interstate 95, U.S. Route 40, Maryland Route 7, and Maryland Route 24. Maryland Route 24 terminates at the main gate of the Edgewood Area of APG (Figure 1-1). An extensive amount of passenger and cargo rail traffic travels on Amtrak and Conrail lines, which run northeast to southwest along the Edgewood Area Installation boundary (Figure 1-2).

Land use surrounding APG is a mix of commercial and residential, but also includes some agricultural. Industry is most concentrated along Route 40. Primary population centers near the Edgewood Area of APG include the communities of Joppatowne/Magnolia (population 9,411), one mile west of the post; Edgewood (population 25,992), directly adjacent to the main gate; and Bel Air (population 36,136), approximately eight miles north of the Edgewood Area of APG on Route 24 (Kropp 1996). Other smaller communities surrounding the Edgewood Area include Abingdon, Belcamp, Chase, and Van Bibber. The Harford County Department of Planning and Zoning estimates the 1995 population of Harford County was 209,130, a 15 percent growth since 1990. From 1980 to1990, population declined in the towns and cities of Harford County and increased along the Route 24 and Route 40 corridors, especially on the fringes of the towns and cities (Harford County Department of Planning and Zoning, 1996).

The Harford County Office of Economic Development lists APG as Harford County's largest employer, with a combined civilian and military staff of 14,780 as of December 31, 1995. A total of 4,130 employees of APG are civilians (Filbert, 1996). APG provides employment for 6.1

Table 3-9. Aquifer Types Identified by Code of Maryland Annotated Regulations (COMAR) 26.08.02.09B

Type I Aquifer	
Transmissivity (T)	Greater than 1,000 gallons/day/foot
Permeability (Hydraulic Conductivity - K)	Greater than 100 gallons/day/foot^2
Total Dissolved Solids (TDS)	Less than 500 mg/L
Discharge Quality Criteria (under COMAR 26.08.02.09C)	The characteristics or constituents of waters may not exceed primary or secondary standards for drinking water
Type IIA Aquifer	
Transmissivity	Greater than 10,000 gallons/day/foot
Permeability (Hydraulic Conductivity - K)	Greater than 100 gallons/day/foot^2
Total Dissolved Solids (TDS)	Between 500 and 6,000 mg/L
Discharge Quality Criteria (under COMAR 26.08.02.09C)	The characteristics or constituents of waters after treatment may not exceed primary or secondary standards for drinking water, except for TDS as adopted in COMAR 26.04.01 and 26.08.02.09B(2)
Type IIB Aquifer	
Transmissivity	Between 1,000 and 10,000 gallons/day/foot
Permeability (Hydraulic Conductivity - K)	Greater than 100 gallons/day/foot^2
Total Dissolved Solids (TDS)	Between 500 and 1,500 mg/L
Discharge Quality Criteria (under COMAR 26.08.02.09C)	The characteristics or constituents of waters after treatment may not exceed primary or secondary standards for drinking water, except for TDS as adopted in COMAR 26.04.01 and 26.08.02.09B(2)
Type III Aquifer	
T and K Values, and TDS Results	All aquifers other than Type I or Type II aquifers
Discharge Quality Criteria (under COMAR 26.08.02.09C)	Characteristics or constituents of waters do not meet Type I or Type II quality criteria

percent of Harford County's civilian labor force (Wagner, 1996). Military and civilian personnel working within the Northern Bush River Area include security guards and military police, staff members of the ECBC and DIO involved in storage activities, DIO maintenance workers, and groundskeepers.

The Edgewood Area of APG houses approximately 1,363 on-site personnel in single family housing and group barracks. Residential and recreational areas are within a one-mile radius of the Northern Bush River Area. On-site military personnel communities within a one mile radius are Skippers Point Housing, Senior Enlisted Quarters on Chevron Drive, Senior Enlisted Quarters on Grant Court, Company Grade Quarters on Everett Road, and Senior and Field Grade Officers Quarters on Everett Road. These five communities combined contain 140 duplexes, 36 single-family housing units, 36 multiplex units, and 24 apartments. Playgrounds associated with on-post communities, a youth center, and day care facility also fall within a one-mile radius of the Northern Bush River Study Area (Advanced Sciences, Inc., 1995).

On-post APG directorate offices and buildings are included in the one-mile radius of the Northern Bush River Area. Weide Airfield is southeast of the Northern Bush River Area. Offices, maintenance buildings, and warehouses associated with ECBC and DIO are within the area. The Edgewood Area Wastewater Treatment Plant near Beach Point lies south of the Bush River peninsula. Buildings and laboratories of the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) and U.S. Army Medical Research Institute of Chemical Defense are west of the area. The open waters of Lauderick Creek and the Bush River are north and east of the Northern Bush River Area, respectively. Kings Creek is closed to the public.

Recreational activities within the Edgewood Area include hunting, trapping, shoreline fishing and crabbing, boating, sports, and picnicking. Active and retired military personnel and families, as well as civilians use recreational sites. Downstream areas of the Bush River support both commercial and recreational fishing. Boat traffic within Installation boundaries is restricted by range control during firing exercises and enforced by APG patrol boats. The Army has posted no trespassing signs on shorelines informing potential trespassers of UXO dangers. Numerous public and private boat ramps and marinas in the upper reaches of the Bush River provide access to the water. The Skippers Point boat ramp is approximately 600 feet northeast of the Cluster 35 DPW Storage Areas (Figure 1-3), and the Gunpowder Neck Boat Club is located within the northeastern shore of Northern Bush River. Skippers Point recreational facility offers camp areas, equipment and boat rentals, and picnic areas. Designated deer hunting areas include the northern shorelines of Lauderick Creek. All hunting areas bordering Kings Creek are currently closed due to the potential presence of UXO (U.S. Department of the Army, 1994 and verbal discussions with Director of Law Enforcement & Security, APG, MD, 1996).

3.7 Ecology

The Northern Bush River Area contains forest, fields and wetlands habitats that support varieties of wildlife species and vegetation. Currently, there are no known occurrences of endangered plant or wildlife species in the Northern Bush River Area. Bald eagles, previously listed under Federal protection status as threatened, are known to forage in and around the Bush River Study Area. The closest known active nesting area is on the north shoreline of Lauderick Creek, approximately 3,000 feet north of the Northern Bush River Area.

Tulip, oak, maple, sweet gum, and pine trees dominate the secondary growth forest vegetation at the Northern Bush River peninsula (Figure 3-1). Typical forest species of the area include red fox, gray squirrel, white-tailed deer, woodpecker, crows, and a variety of singing birds. Shrubs and native grasses are found in the open fields. Field species include field mice, voles, cottontail rabbits, bobwhites, mourning doves, killdeer, hawks, and singing birds (ICF Kaiser Engineers, Inc., 1995c).

The wetland ecology in Northern Bush River Area includes pockets of palustrine (fresh water) forested and emergent marsh environments. The majority of the wetlands in the area are estuarine (brackish water) emergent marsh environments. Wetland plants common to the palustrine emergent areas include phragmites, cattails, and rushes. Palustrine forested areas contain red maple and sweet gum, while esturarine emergent species include phragmites, cordgrass, three squares, and rushes (ICF Kaiser Engineers, Inc., 1995c).

Wetland species include muskrats, turtles, snakes, great blue herons, puddle and diving ducks, and a variety of shorebirds, including spotted sandpiper and rails. Estuarine fish that are expected to live in Kings Creek and the Bush River include largemouth and striped bass, carp, white and yellow perch, bluefish, catfish, sunfish, Atlantic silverside, and eels (ICF Kaiser Engineers, Inc., 1995c).

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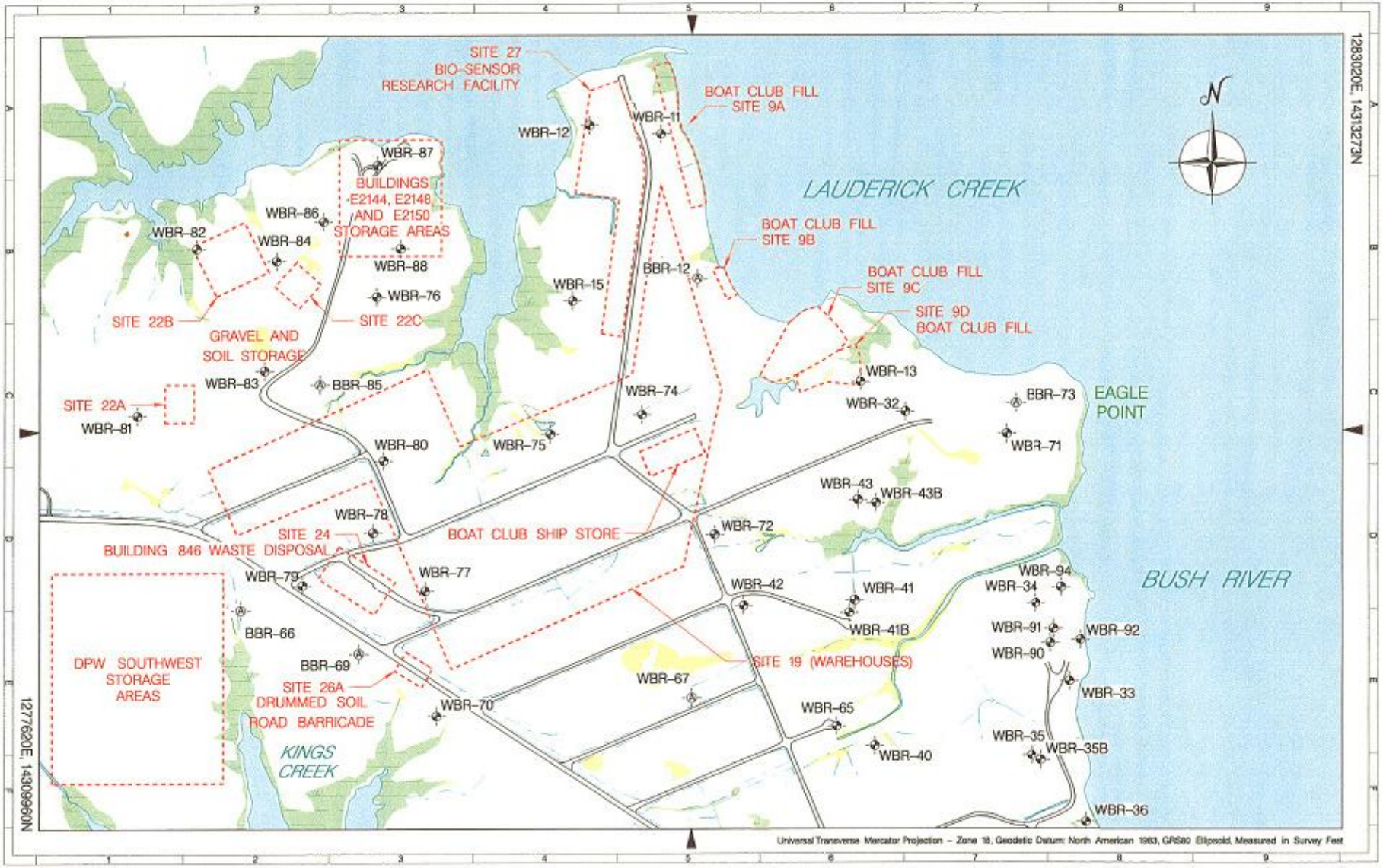
4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents analytical data generated from sampling and analysis of Northern Bush River environmental media. QA/QC samples are assessed to determine the usability and relevance of the validated data. Analytical results and data interpretations were used to determine the presence and impact of contamination at each site. Section 4.4 presents the analysis approach used to compare results to established RI screening-level comparison criteria for determining environmental impacts. Figures 4-1 through 4-3 depict the RI environmental media sampling locations. Conclusions and recommendations in Section 7 are based on the contamination assessments in Sections 4.1 through 4.3 in conjunction with the fate and transport in Section 5, and potential risks in Section 6 associated with the identified contaminants.

4.1 Contamination Assessment of Cluster 7 Boat Club Fill Sites

The Cluster 7 Boat Club Fill Sites consist of four separate locations (i.e., Sites 9A, 9B, 9C, and 9D) where man-made filling activities occurred (DSERTS # EABR07-A), and a former Bio-Sensor Research Facility (DSERTS # EABR07-B) existed, consisting of a former dog kennel and wastewater package treatment plant. Potentially contaminated fill materials were placed in Site 9A and 9D during the early 1940s, and in Sites 9B and 9C in 1988. Operations at the former Bio-Sensor Research Facility began in the late 1960s and ceased in the 1970s. Environmental media sampling and analysis indicate localized or limited environmental impacts. No PCBs, explosive-related compounds, or chemical agent degradation products were detected in Cluster 7 environmental media. Compounds that are not discussed below were either non-detected or below comparison criteria.

The chlorinated VOC chloroform was detected at 4 µg/L in both sampling rounds, and the pesticide heptachlor was detected at 0.018 µg/L in the first sampling round of groundwater from well WBR-11, located adjacent to Fill Site 9A (Figure 4-1). Total arsenic was detected at 5.4 µg/L in the second round of sampling at well WBR-12, located adjacent to the wastewater package treatment plant, below the upper reference (background) limit of 11 µg/L. These concentrations are above the USEPA Region III Risk-Based Concentrations (RBCs) for tap water of 0.152, 0.015, and 0.045 µg/L for these three compounds, respectively. Both sampling rounds from the well WBR-15 contained total iron above the RBCs for tap water and background limits. The highest concentrations of iron were 21,400 and 32,800 µg/L for wells WBR-12 and -15, respectively, which are above the RBCs for tap water of 11,000 µg/L. The upper reference limit for iron is 29,700 µg/L. All gross alpha and gross beta concentrations were either non-detected or within background ranges. No LNAPLs or DNAPLs were detected in Cluster 7 groundwater.



L E G E N D

- Road
- Water
- Topographic Contour
- Stream / Drainage Ditch
- Abandoned Well or Boring
- Site Boundary
- Tidal Wetland
- Non-tidal Wetland
- Monitoring Well

600 400 200 0 300 600 1200

GRAPHICAL SCALE
IN FEET (1" = 600')

TITLE: SURFICIAL AQUIFER GROUNDWATER MONITORING WELL LOCATIONS

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B. JOYCE	T. DEREAMER	01-22-03	1-1

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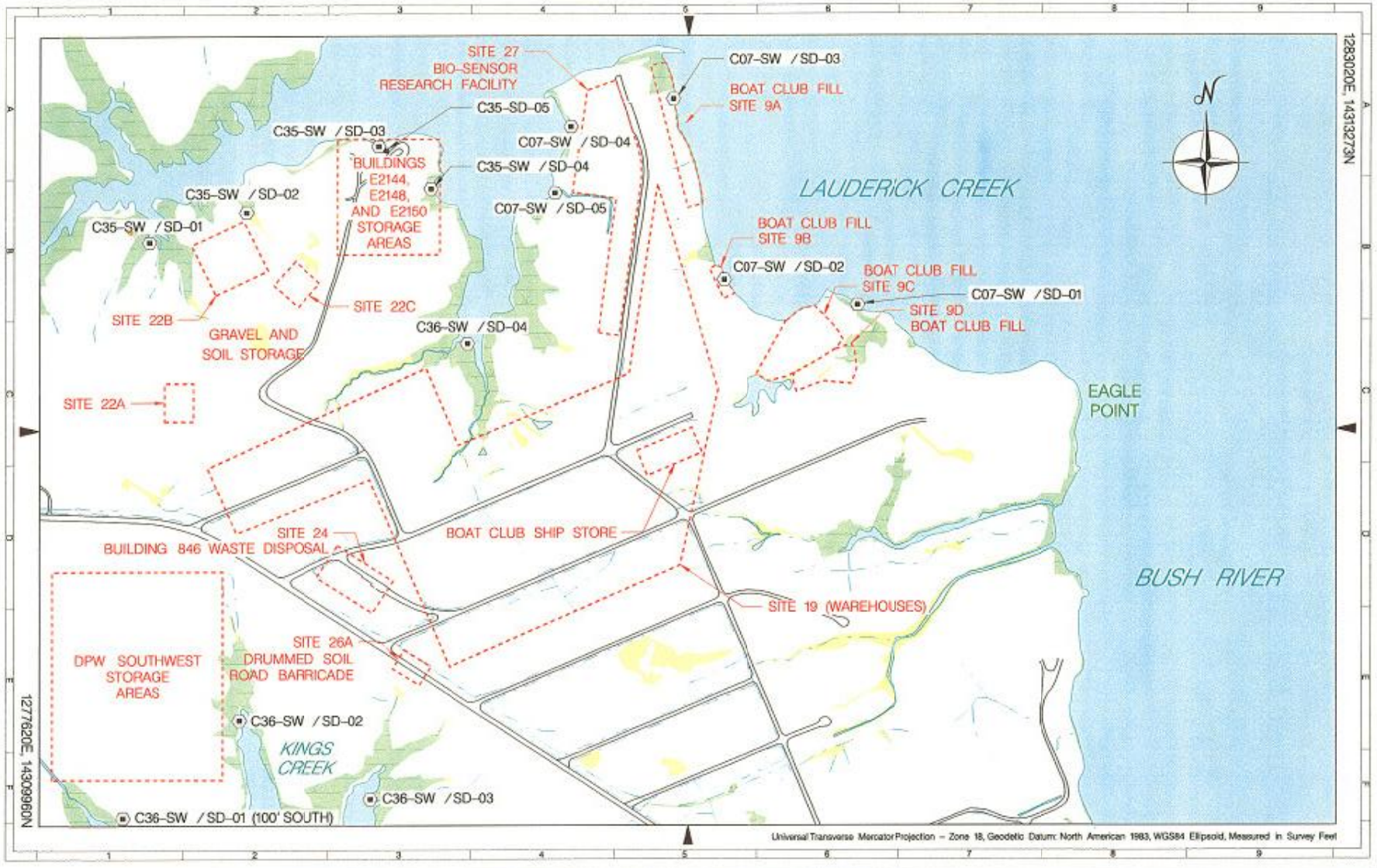

L E G E N D

- Water
- Tidal Wetland
- Non-tidal Wetland
- Sediment Sample
- Road
- Stream / Drainage Ditch
- Site Boundary
- Surface Water / Sediment Sample

600 400 200 0 300 600 1200

GRAPHICAL SCALE
IN FEET (1" = 600') 1:7200

NORTHERN BUSH RIVER SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

6095 Marshalee Drive
Elkridge, MD 21075
(800) 727-6677
www.gpworldwide.com

CARTOGRAPHER:	APPROVED BY:	DATE:	FIGURE:
B. JOYCE	T. DEREAMER	02-07-02	4-2

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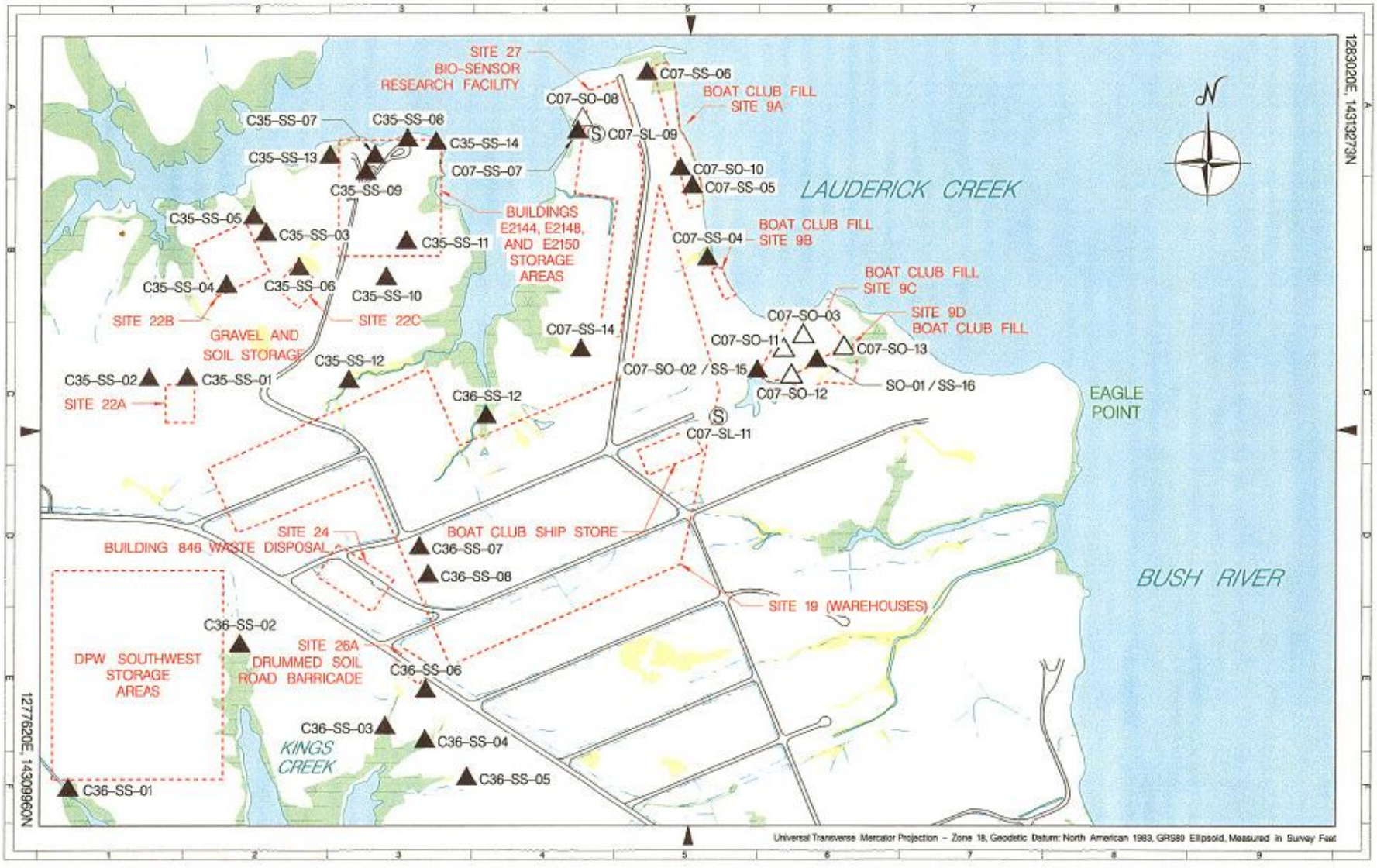

L E G E N D

- Water
- Tidal Wetland
- Non-tidal Wetland
- Road
- Stream / Drainage Ditch
- Site Boundary
- Sludge Sample
- Surface Soil Sample
- Subsurface Soil Sample

600 400 200 0 300 600 1200

GRAPHICAL SCALE
IN FEET (1" = 600')

1:7200

TITLE: NORTHERN BUSH RIVER SURFACE SOIL, SUBSURFACE SOIL AND SLUDGE LOCATIONS

6095 Marshalee Drive
Elkridge, MD 21075
(800) 727-6677
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CARTOGRAPHER:	APPROVED BY:	DATE:	FIGURE:
B. JOYCE	T. DEREAMER	01-22-03	1-3

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Chloroform was detected at 3 µg/L in the first round and at 6 µg/L in the second round of surface water sampling at location C7-SW-05, located southwest of the former dog kennel (Figure 4-2). These detections were above the recreational water RBCs of 1.5 µg/L. Two pesticides, delta-BHC and endrin aldehyde, were detected in the second round of surface water sampling. The highest concentrations of delta-BHC and endrin aldehyde were 0.0012 and 0.004 µg/L, respectively. There are no available comparison criteria for these pesticides. The SVOC di-n-butylphthalate was detected at 1 µg/L in the second round from location C07-SW-01, which is above the USEPA Region III Biological Technical Assistance Group (BTAG) ecological screening-level of 0.3 µg/L. The total metals aluminum, iron, and zinc were detected above BTAG screening levels. All aluminum, arsenic, iron, and zinc concentrations were within reference (background) limits. Arsenic was detected between 2.2 and 2.6 µg/L in the first round of surface water sampling at locations C7-SW-02, -03, and-04, which is above the recreational water RBCs of 0.45 µg/L, but below the upper reference limit of 3.2 µg/L. Gross alpha concentrations ranged from non-detected to 3 picoCuries per Liter (pCi/L) at one location during one round, and gross beta concentrations ranged from non-detected to 6 pCi/L at four locations during both rounds of surface water sampling.

The pesticide 4,4'-DDT and its degradation products 4,4'-DDD and 4,4'-DDE were detected at sediment sampling locations C7-SD-04 and C7-SD-05 (Figure 4-2). Location C7-SD-04 contained 4,4'-DDD at 160 µg/Kg and 4,4'DDE at 44 µg/Kg. Location C7-SD-05 contained 4,4'-DDD at 80 µg/Kg, 4,4'DDE at 32 µg/Kg, and 4,4'-DDT at 11 µg/Kg. These concentrations are above the BTAG screening levels for 4,4'-DDD, 4,4'DDE, and 4,4'-DDT of 16, 2.2, and of 1.58 µg/Kg, and the reference (background) concentrations of 8.3, 11, and 15.4 µg/Kg, respectively. Both locations are on the tributary shoreline west of the former Bio-Sensor Research Facility and probably the result of past pesticide use. Location C7-SD-04 contained arsenic at 5.5 mg/Kg, which is above the recreational sediment RBC of 4.3 mg/Kg, but below the upper reference limit of 18.9 mg/Kg. Both detected at 1.7 mg/Kg, selenium and silver concentrations were above reference limits of 1.54 and 0.875 mg/Kg, respectively. The silver concentration is also above the BTAG screening level of 1 mg/Kg. Total chromium at five locations and zinc at two locations were above BTAG screening levels, but below upper reference (background) limits. Gross alpha and gross beta were detected below background limits. The natural occurring radiological analyte potassium-40 was detected in four sediment samples, with the highest concentration of 44.8 picoCuries per gram (pCi/g) at location C7-SD-01.

The military clothing impregnate degradation product TCPU was detected at 2,500 µg/Kg at surface soil location C7-SS-15 within Fill Site 9C (Figure 4-3). There are no available comparison criteria for TCPU. Although the concentrations are below comparison criteria, the chlorinated

VOC trichloroethene was detected at 26 µg/Kg at location C7-SS-04 downgradient of Fill Site 9B, and the chlorinated VOC tetrachloroethene was detected at 1 µg/Kg at location C7-SS-05 within Fill Site 9A. The sum of 4,4'-DDT and its degradation products 4,4'-DDD and 4,4'-DDE (DDTr) were detected at locations C7-SS-04, -14, -15, and -16 above BTAG screening levels and/or upper reference limits. Location C7-SS-04 (downgradient of Fill Site 9A) and location C7-SS-16 (within Fill Site 9D) contained DDTr concentrations of 567 and 412 µg/Kg, respectively. Total aluminum, arsenic, beryllium, chromium, copper, iron, lead, nickel, vanadium, and zinc were detected above BTAG screening levels, but below reference (background) limits. Zinc concentrations of 622 mg/Kg at location C7-SS-07 near the former wastewater treatment package plant were above the reference limit of 242 mg/Kg. Gross alpha and gross beta concentrations were below background limits. The natural occurring radiological analyte potassium-40 was detected in three surface soil samples, with the highest concentration of 45.9 pCi/g at location C7-SS-04.

TCPU was detected at 1,200 µg/Kg in subsurface soil sample C7-SO-03, within Fill Site 9C (Figure 4-3). Trichloroethene was detected at 2 µg/Kg and below comparison criteria in subsurface soil sample C7-SO-01, within Fill Site 9D. Subsurface soil sample C7-SO-03 contained 18 PAHs ranging from 150 to 7,400 µg/Kg, and C7-SO-11 contained 10 PAHs ranging from 180 to 530 µg/Kg, which are above reference (background) limits. With the exception of iron at 25,500 mg/Kg in sample C7-SO-01, which is above the upper reference limit of 23,500 mg/Kg, all other detected metal concentrations were within reference limits. Gross alpha and gross beta concentrations were below background limits. Cesium-137 was detected as high as 0.21 pCi/g. Potassium-40 was detected as high as 48.7 pCi/g at location C7-SO-02. With the exception of zinc at 102 µg/L and silver at 4 µg/L, all detected compounds in the sludge water sample C7-SL-09 at the wastewater package treatment plant were below reference limits for surface water.

4.2 Contamination Assessment of Cluster 35 DPW Storage Areas

The Cluster 35 DPW Storage Areas consist of three Gravel and Soil Storage Sites (DSERTS # EABR35-A), and Buildings E2144, E2148, and E2150 (DSERTS # EABR35-B). Aerial photographs in 1951 displayed unidentified stored materials at Storage Sites 22A and 22B. Parts of these sites were located within a former fenced and secured storage area. Potentially contaminated soil has been stored at Site 22C since 1989. Environmental media sampling and analysis indicate localized or limited environmental impacts. No PCBs, explosive-related compounds, or chemical agent degradation products were detected in Cluster 35 environmental media. Compounds that are not discussed below were either non-detected or below comparison criteria.

Under separate groundwater sampling events and during one round, samples from well WBR-81

829, and 250 µg/Kg, respectively. Total aluminum, beryllium, chromium, copper, iron, lead, vanadium, and zinc were detected above BTAG screening levels, but below reference (background) limits. Location C35-SS-14 contained arsenic at 28.8 mg/Kg, which is above the RBCs for residential soil of 0.43 mg/Kg and the above upper reference limit of 5.29 mg/Kg. Location C35-SS-08 (near building E2150) contained nickel at 63.9 mg/Kg, which is above the BTAG screening level of 2 mg/Kg and the upper reference limit of 24.1 mg/Kg. All gross alpha concentrations were within background ranges. Locations C35-SS-03 and -04 contained gross beta concentrations at 9.5 and 9.6 pCi/g, respectively, which is above the background limit of 5.8 pCi/g.

4.3 Contamination Assessment of Cluster 36 Warehouse Sites

The Cluster 36 Warehouse Sites contain nine Warehouse Storage Areas (DSERTS # EABR36-A), the Building 846 (E2194) Waste Disposal Site (DSERTS # EABR36-B), a former Drummed Soil Road Barricade Site during 1986 and 1987, the Boat Club Ship Store (Building E2169), and DPW Southwest Storage Areas (DSERTS # EABR36-A). The warehouses were built for material storage in the early 1940s. A fill site lies north of warehouse E2168. Construction work in the 1980s uncovered and removed the burned remains of gas masks and gas mask filters in the northern parking lot of Building E2194. A septic tank associated with the Boat Club Ship Store is unused. Environmental media sampling and analysis indicate localized or limited environmental impacts. No PCBs, explosive-related compounds, or chemical agent degradation products were detected in Cluster 36 environmental media. Compounds that are not discussed below were either non-detected or below comparison criteria.

Chloroform was detected at 2 µg/L in second round samples from well WBR-74, which is above the RBC for tap water of 0.152 µg/L. The pesticide heptachlor epoxide was detected in well WBR-80 at 0.008 µg/L, which is above the RBC for tap water of 0.0074 µg/L. During both sampling rounds, groundwater from wells WBR-75, -78, and –80 contained total arsenic above the RBC for tap water of 0.045 µg/L. Arsenic results from samples at well WBR-75 were 13.2 and 15.8 µg/L, which are above the upper reference (background) limit of 11 µg/L. Arsenic results for well WBR-78 and –80 were below background limits. First and second round samples from well WBR-75 contained total manganese at 1,790 and 1,880 µg/L, respectively, which are above the RBC for tap water of 730 µg/L and upper reference limit of 866 µg/L. Both sampling rounds from the well WBR-78 contained total iron above the RBC for tap water of 11,000 µg/L and background limits of 29,700 µg/L. The highest concentration of total iron was 55,900 µg/L. All gross alpha concentrations were either non-detected or within background ranges. Under separate groundwater sampling events and during one round, samples from wells WBR-74 and –75 contained gross beta concentrations at 31 and 61 pCi/L, respectively, which are above the background limit of 17.3

pCi/L. No LNAPLs or DNAPLs were detected in Cluster 36 groundwater.

First round surface water samples from location C36-SW-02 contained chloromethane at 28 µg/L, which is above the recreation surface water RBC of 21.1 µg/L. In the second round of sampling, di-n-butyl phthalate was detected at locations C36-SW-01 and -02 at 2 and 1 µg/L, respectively, which is above the BTAG screening level of 0.3 µg/L. Aluminum, iron, and lead concentrations were above BTAG screening-levels, but below background limits. During the second round of sampling from C36-SW-03, arsenic was detected at 6.5 µg/L, which is above the recreational surface water RBC of 0.45 µg/L; cadmium was detected at 3.3 µg/L, which is above the BTAG screening level of 0.53 µg/L; and mercury was detected at 0.11 µg/L, which is above the BTAG screening level of 0.012 µg/L and background limit of 0.0001 µg/L. Gross alpha and gross beta concentrations range from non-detected to 15 pCi/L.

Sediment sample C36-SD-04 contained the pesticide 4,4'-DDT degradation products of 4,4'-DDD and 4,4'-DDE at 9.5 and 9.4 µg/Kg, respectively. These concentrations are either above the BTAG screening levels for 4,4'-DDD and 4,4'DDE of 16 and 2.2 µg/Kg, or the reference (background) concentrations of 8.3 and 11 µg/Kg, respectively. Location C36-SD-02 contained 4,4'DDE at 3.2 µg/Kg. Total chromium at four locations was detected above BTAG screening levels, but below upper reference (background) limits. Mercury was detected at 0.18 mg/Kg at location C36-SD-04, which is above the BTAG screening level of 0.15 mg/Kg, but below the upper reference limit of 0.398 mg/Kg. All gross alpha and gross beta concentrations were detected below background levels.

PAHs were detected in the following surface soil samples above BTAG screening levels, but below reference (background) limits: one PAH in C36-SS-01, two in C36-SS-02, seven in C36-SS-04, and five in C36-SS-12. The 4,4'-DDT degradation products of 4,4'-DDD and/or 4,4'-DDE were detected in six surface soil samples above BTAG screening-levels and/or background limits. The highest concentration of 4,4'-DDD and 4,4'-DDE occurred at location C36-SS-04 at 730 and 1,000 µg/Kg, respectively. Total chromium, iron, lead, vanadium, and zinc were detected above BTAG screening levels, but below reference (background) limits. Locations C36-SS-04 and -12 contained arsenic at 32.5 and 5.5 mg/Kg, which is above the RBCs for residential soil of 0.43 mg/Kg and upper reference limit of 5.29 mg/Kg. Location C36-SS-01 contained beryllium at 1.7 mg/Kg, copper at 43.2 mg/Kg, and nickel at 30.2 mg/Kg, which are above the BTAG screening-levels of 0.02, 15, and 2 mg/Kg, and upper reference limits of 1.42, 27.5, and 24.1 mg/Kg, respectively. Gross alpha concentrations as high as 16 pCi/g and gross beta concentrations as high as 14.3 pCi/g were detected above background limits of 9.1 and 5.8 pCi/g, respectively, at locations C36-SS-03, -04, and -05. Ten SVOCs, two pesticides, and 10 metals were detected in the sludge water sample

C36-SL-11, located east of the Boat Club Ship Store E2169. The concentrations were above reference limits for surface water.

4.4 Approach to Analysis of Sampling Results

This section discusses the approach used for evaluating Northern Bush River sample results for the contamination assessments in Sections 4.1 through 4.3. The intent of presenting detected compounds above established RI comparison criteria is to determine environmental impacts, assess contaminant sources, and evaluate contaminant migration. Compounds detected above RI comparison criteria are not COPCs identified in the risk assessments. Therefore, the RI comparison criteria outlined in this section differs from the risk assessment selections for the identified COPCs. The Baseline Risk Assessment in Section 6 focuses on two separate evaluations of the RI analytical results based on the potential for human health and ecological risks. The human health risk assessment used adjusted RBCs for non-carcinogenic compounds, industrial soil RBCs in selected data groupings, and reference (background) levels to statistically screen and identify potential human health COPCs. The screening-level ecological risk assessment used USEPA Region III BTAG screening levels, toxicity reference values, and background ranges and levels to statistically screen and identify potential ecological COPCs. Comparisons in Section 4 are in support of discussion related to the nature and extent of contamination, and are not part of the Baseline Risk Assessment in Section 6 and Appendix G.

Contaminants found in environmental media are compared to various criteria, depending on the type of contaminant, the medium being investigated, and potential exposure routes. Section 4 discusses detected compounds present in environmental media above the RI comparison criteria. Tables in Appendices A through E present a direct comparison of detected compounds in environmental media to applicable criteria.

4.4.1 Selection of RI Comparison Criteria

All detected compounds in environmental media were compared to human health RBCs from the *Risk-Based Concentration Table* (USEPA Region III, 2002). As discussed below, specific types of RBCs were used for each environmental medium. Groundwater results were compared to upper reference limits, as obtained from the *APG reference Sampling and Analysis Program Groundwater Reference Data Report* (ICF Kaiser Engineers, Inc., 1995a). Surface water, sediment, surface soil, and subsurface soil results were compared to the maximum BTAG screening levels for environmental media (USEPA Region III, 1997) and the upper (maximum) reference limits for each environmental medium, as taken from the *APG Reference Sampling and Analysis Program Soil, Sediment, and Surface Water Reference Data Report* (ICF Kaiser

Engineers, Inc., 1995b). The reference sampling provided reference data to identify concentrations of naturally occurring and anthropogenic analytes in environmental media surrounding APG. Reference samples are intended to measure background concentrations in environmental media representative of APG. Tables 4-1 through 4-4 contain the reference data ranges for groundwater, surface water, sediment, and surface soil, respectively.

Compounds detected in groundwater were compared to the RBCs for tap water. These human health screening levels for groundwater exposures are derived from reference doses or carcinogenic potency slopes, which are combined with standard default exposure scenarios Appendix A presents the data results for groundwater.

Compounds detected in surface water were compared to the values that are one order of magnitude (i.e., 10 times) above the RBCs for tap water. These human health screening levels for surface water are termed recreational water RBCs, allowing a comparison to recreational exposures that are more likely to occur in this medium. Appendix B presents the data results for surface water.

Compounds detected in sediment were compared to the values that are one order of magnitude (i.e., 10 times) above the RBCs for residential soil. These human health screening levels for sediment are termed recreational sediment RBCs, allowing a comparison to recreational exposures that are more likely to occur in this medium. Appendix B also presents the data results for sediment.

Compounds detected in surface and subsurface soil were also compared to the RBCs for residential soil. These human health screening levels allow a conservative comparison of potential residential exposures to soil. Appendices C and D present the data results for surface soil and subsurface soil, respectively.

Compounds detected in the two sludge samples analyzed as water were compared to the values that are one order of magnitude (i.e., 10 times) above the RBCs for tap water and upper reference (background) limits for surface water. Sludge results do not have directly available comparison criteria. The intent of using these comparison criteria was to allow some evaluation of water contamination in the two septic tanks. Appendix E presents the data results for sludge.

4.4.2 Exceptions to Reporting Format Approach

Exceptions to the reporting format approach outlined in Section 4.4.1 are due to (1) the lack of comparison criteria, (2) the migration potential of certain detected concentrations below the RI comparison criteria, or (3) the uncertainty in the results.

Table 4-2. Surface Water Reference Data Limits*

Inorganic Analyte	Spring Values			Fall Values		
	Mean Reference Limit (µg/L)	Lower Limit (µg/L)	Upper Limit (µg/L)	Mean Reference Limit (µg/L)	Lower Limit (µg/L)	Upper Limit (µg/L)
Aluminum	1,470	65.0	10,200	665	64.1	2,480
Antimony	ND	ND	25	1.62	1.5	3.9
Arsenic	1.14	1	3.2	1.1	1	3.2
Barium	28.2	8.5	61	51.4	19.4	179
Beryllium	ND	ND	2.5	0.1	0.2	0.2
Cadmium	ND	ND	2.5	ND	ND	2.5
Calcium	13,400	2,190	37,900	39,700	3,500	83,800
Chromium	3.19	2.5	14.2	2.97	2.5	6.7
Cobalt	3.9	2.5	20.7	3.81	2.5	21.1
Copper	3.28	2.5	9.7	2.57	2.5	5.5
Iron	2,630	265	26,700	1,560	152	20,600
Lead	2.1	0.75	17.95	1.6	0.75	6.3
Magnesium	6,670	1,010	14,000	84,390	2,560	229,000
Manganese	249	26.2	2,440	311	20	4,810
Mercury	ND	ND	0.2	ND	ND	0.2
Nickel	6.25	5	23.6	6.38	5	23.7
Potassium	2,770	1,220	7,370	26,100	1,470	73,400
Selenium	ND	ND	2.5	ND	ND	6.25
Silver	ND	ND	2.5	0.32	0.15	0.7
Sodium	23,500	1,810	92,900	668,000	3,950	2,010,000
Thallium	ND	ND	6.25	ND	ND	2.5
Vanadium	5.81	2.5	20.3	11.5	2.5	23.2
Zinc	16.1	2.5	78	9.8	2.5	61.9
Salinity (%)	0.03	0	0.3	2.75	0	7.6
TDS (mg/L)	142	10	338	2,420	57	6,940
TSS (mg/L)	38.5	4.	220	19.9	2	62

* *APG Reference Sampling and Analysis Program Soil, Sediment, and Surface Water Reference Data Report,* (ICF Kaiser Engineers, Inc., 1995b).

TDS = Total Dissolved Solids
TSS = Total Suspended Solids
ND = Non-detected; upper limits for these compounds are half of the detection limit.

Table 4-3. Sediment Reference Data Limits*

Inorganic Analytes	Mean Reference Limit (mg/kg)	Lower Limit (mg/kg)	Upper Limit (mg/kg)	Organic Compounds	Mean Reference Limit (µg/Kg)	Lower Limit (µg/Kg)	Upper Limit (µg/Kg)
Aluminum	11,700	537.0	28,050	2-Methylnaphthalene	113	50	300
Antimony	0.66	0.53	1.8	4-Methylphenol	84.2	61	91
Arsenic	4.07	0.424	18.9	alpha-Chlordane	1.28	0.6	5
Barium	55.8	2.74	130	Anthracene	82.7	52	170
Beryllium	1.23	0.086	2.59	Benzo(a)anthracene	121	79	280
Cadmium	0.48	0.073	3.42	Benzo(a)pyrene	149	56	250
Calcium	1,630	88.8	9,590	Benzo(b)fluoranthene	124	31	370
Chromium	34.1	4.92	117	Benzo(g,h,i)perylene	75	35	95
Cobalt	14.6	0.976	35.1	Benzo(k)fluoranthene	86.6	34	140
Copper	25.8	2.11	78.7	bis(2-Ethyhexyl)phthalate	492	40	9,300
Iron	22,300	2,540	54,300	Chrysene	127	63	330
Lead	31	3.56	91.1	Diethyl phthalate	48.4	40	60
Magnesium	2,630	153	6,510	4,4'-DDD	1.78	0.6	8.3
Manganese	481	6.34	1,590	4,4'-DDE	2.24	0.6	11
Mercury	0.15	0.058	0.398	4,4'-DDT	1.6	0.6	15.4
Nickel	25	1.89	70.1	Fluoranthene	146	0.6	600
Potassium	1,250	89.1	3,730	Fluorene	80.6	40	140
Selenium	0.4	0.491	1.54	gamma-BHC (Lindane)	1.25	0.6	3.14
Silver	ND	ND	0.875	Heptachlor	1.3	0.6	3.14
Sodium	2,060	293	6,310	Indeno(1,2,3-cd)pyrene	95.9	46	110
Thallium	0.29	0.293	0.52	Naphthalene	92.5	54.	470
Vanadium	38.5	4.74	93	Phenanthrene	108	31	600
Zinc	110	8.27	284	Pyrene	142	44	480
Gross Alpha (pCi/g)	6.23	0.5	12.7				
Gross Beta (pCi/g)	4.99	0.4	15				

* *APG Reference Sampling and Analysis Program Soil, Sediment, and Surface Water Reference Data Report*, (ICF Kaiser Engineers, Inc., 1995b).

ND = Non-detected; upper limits for this compound are half of the detection limit.

Table 4-4. Surface Soil Reference Data Limits*

Inorganic Analytes	Mean Reference Limit (mg/kg)	Lower Limit (mg/kg)	Upper Limit (mg/kg)
Aluminum	7,940	1,390	17,300
Antimony	3.14	2.65	4.9
Arsenic	2.57	1.04	5.29
Barium	43.6	9.83	125
Beryllium	0.44	0.266	1.42
Cadmium	0.34	0.266	1.4
Calcium	534	66.8	1,980
Chromium	16.8	3.53	68.9
Cobalt	7.25	0.682	25.6
Copper	8.72	3	27.5
Iron	12,300	2,610	23,500
Lead	21.63	5.49	117
Magnesium	1,010	63	3,920
Manganese	276	4.95	1,140
Mercury	0.04	0.025	0.07
Nickel	8.37	1.99	24.1
Potassium	384	70.6	1,700
Selenium	0.21	0.13	0.497
Silver	ND	ND	0.492
Sodium	7.46	206	937
Thallium	ND	ND	0.245
Vanadium	24.6	8.8	59.2
Zinc	37	4.89	242
Gross Alpha (pCi/g)	5.22	0.925	9.1
Gross Beta (pCi/g)	2.96	0.6	5.8

Organic Compounds	Mean Reference Limit (µg/kg)	Lower Limit (µg/kg)	Upper Limit (µg/kg)
Acenaphthene	46	35	140
Benzo(a)anthracene	71.3	53	230
Benzo(a)pyrene	109	57	440
Benzo(b)fluoranthene	73.1	35	350
Benzo(g,h,i)perylene	108	73	200
Benzo(k)fluoranthene	65.8	29	140
Chrysene	78.6	67	380
Diethyl phthalate	47.1	41	72
4,4'-DDD	0.96	<1	7.83
4,4'-DDE	16.9	4.08	392
4,4'-DDT	7.62	1.62	143
Fluoranthene	62.3	20	320
Indeno(1,2,3-cd)pyrene	101	40	210
Phenanthrene	52	25	170
Pyrene	73.7	38	620

* *APG Reference Sampling and Analysis Program Soil, Sediment, and Surface Water Reference Data Report*, (ICF Kaiser Engineers, Inc., 1995b).

ND = Non-detected; upper limits for these compounds are half of the detection limit.

Some analytes do not have available RBCs, BTAG screening levels, or reference (background) data. Essential human nutrients (i.e., calcium, magnesium, potassium, and sodium) are not extensively discussed because they lack risk-based criteria. If no comparison criteria are available for a contaminant, then all concentrations of that contaminant detected above the laboratory's detection limit are presented.

Analytes found at levels below the RI comparison criteria may also be presented if data interpretations show a continuing trend of contamination. For instance, if low-level contamination (below the RI comparison criteria) is detected in a well down gradient from a group of wells containing gross contamination, those lower concentrations will be presented to establish the total extent of impact. All detections of chlorinated VOCs were reported because of their tendency to migrate. Military-unique compounds, specifically chemical agent degradation products and explosive-related compounds, are presented whether or not the analyte is below, above, or without comparison criteria.

Analytical results rejected by the validator are not discussed. Section 4.4.3 presents an assessment of data usability. Analytes that have been determined to be present in samples due to laboratory or field contamination are not discussed. Section 4.4.4 presents an assessment of laboratory and field contamination. In addition, the potential nerve agent degradation products isopropylmethylphosphonic acid and methylphosphonic acid are not discussed. These compounds were detected in first round groundwater and surface water samples at five locations (i.e., WBR-75, -77, and -78, and C36-SW-01 and -02), and not detected in the second round samples. These detections are believed to be false positives due to matrix interferences from high concentrations of inorganic analytes, primarily multivalent metal cations and associated cations. The original analytical method has been modified with a sample pretreatment protocol to remove the effects of the interferences. The samples corresponding with the isopropylmethylphosphonic acid and methylphosphonic acid detections were not reanalyzed using the modified method; therefore, the original detections were validated for the identified samples. The human health risk assessment used available RBCs for these compounds to evaluate their potential risks.

4.4.3 Usability of Chemical Analysis Results

STEP validated RI sample results for two rounds of groundwater; two rounds of surface water; and one round each of sediment, surface soil subsurface soil, and sludge. VOCs, SVOCs, and pesticide analyses were validated according to *Region III Modifications to National Functional Guidelines for Organic Data Review, Multi-Media, Multi-Concentration (OLM01.0-OLM01.9)* (USEPA Region III, 1994). Metals and cyanide analyses were validated according to *Region III*

Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses (USEPA Region III, 1993). Analyses for explosive-related compounds, chemical agent degradation products, radiological analytes, and general chemical parameters were validated according to the intent of the National Functional Guidelines. During the data validation process, QC samples, instrument calibrations, sample chromatograms, holding times, chain of custody forms, and sample handling procedures were reviewed. Based on this review, sample results were qualified and some analyses were rejected. Appendices A through E includes the validation qualifiers used for the detected compound summary tables. Overall, the laboratory data are acceptable as reviewed and qualified, and meet the contractual QA/QC requirements (STEP, 1996a through d). Table 4-5 provides data usability summaries for all environmental media sampling results.

4.4.4 Evaluation of Laboratory and Field Contamination

Contaminants detected in laboratory method blanks and blanks collected in the field indicate that the contaminant could be present due to sample handling procedures. Sample results determined to be present from laboratory or field contamination are qualified "B" by the validator. Analytes that are common laboratory contaminants are qualified if detected at less than 10 times the blank concentration. All other analytes are qualified if detected at less than five times the blank concentration. Analytes determined by the validator to be due to laboratory or field contamination are not considered in the contamination assessment. Appendices A through E include the validation qualifiers used for the detected compound summary tables.

4.5 Summary of Sampling Results

The following sections summarize the analytical data from groundwater, surface water, sediment, surface soil, subsurface soil, and sludge samples from the Northern Bush River Area (STEP, 1996a, 1996b, 1996c and 1996d). This section also includes a summary of the soil gas survey results.

4.5.1 Results of Groundwater Sampling

The RI groundwater investigation consisted of two rounds of sampling from 19 wells in the Northern Bush River Area. Figure 4-1 show the well locations. The sampling team did not detect DNAPLs or LNAPLs during the groundwater sampling investigation. Tables presenting the detected compounds for both rounds of groundwater sampling are provided in Appendix A.

Table 4-5. Data Usability Summary

Analysis	VOCs	SVOCs	Pest/PCBs	Metals	Cyanide	Boron	Explosive-related	Thiodiglycol	Alpha/ Beta	Gamma Scan
Groundwater (Round 1)	19	19	19	38	19	19	19	19	19	0
Groundwater (Round 2)	19	19	19	38	19	4	19	19	19	0
Surface water (Round 1)	13	13	13	26	13	5	13	13	13	0
Surface water (Round 2)	13	13	13	26	13	5	13	13	13	0
Soil	38	38	38	38	38	0	38	38	38	15
Sediment	13	13	13	13	13	0	13	13	13	5
Sludge	2	2	2	2	2	0	2	2	1	0
Total samples (A)	117	117	117	181	117	33	117	117	116	20
Analytes per sample (B)	33	64	28	23	1	1	14	1	2	variable
Total analytes (AxB)	3861	7488	3276	4163	117	33	1638	117	232	152
Total analytes rejected	0	5	7	38	7	0	0	0	0	0
Percent analytes rejected	0%	0.07%	0.2%	0.9%	6%	0%	0%	0%	0%	0%

VOCs - volatile organic compounds
SVOCs - semivolatile organic compounds
PCBs - polychlorinated biphenyls
Pest - pesticides

Table 4-5. Data Usability Summary (continued)

Analysis	Bromide/Chloride/ Fluoride/Nitrate/ Silica/Sulfate/TDS	Alkalinity/ Hardness	Phenolics/ Phosphorus	Total Organic Carbon	DIMP/DMMP	Organosulfers	IMPA/MPA	TCPU
Groundwater (Round 1)	19	19	19	0	19	19	19	0
Groundwater (Round 2)	4	4	19	0	19	19	19	0
Surface water (Round 1)	0	13	13	0	13	13	13	0
Surface water (Round 2)	0	13	13	0	13	13	13	0
Soil	0	0	38	15	38	38	38	5
Sediment	0	0	13	13	13	13	13	0
Sludge	0	0	2	0	2	1	2	0
Total samples (A)	23	49	117	28	117	116	117	5
Analytes per sample (B)	7	2	2	1	2	7	2	1
Total analytes (AxB)	161	98	234	28	234	812	234	5
Total analytes rejected	0	0	1	0	0	7	12	0
Percent analytes rejected	0%	0%	0.4%	0%	0%	0.9%	5%	0%

TDS - total dissolved solids
DIMP - diisopropylmethylphosphonate
DMMP - dimethylmethylphosphonate
IMPA - isopropylmethylphosphonic acid
MPA - methyl phosphonic acid
TCPU - N,N'-bis(2,4,6-trichlorophenyl)urea

All detections of organic and inorganic compounds were screened against selected RI comparison criteria outlined in Section 4.4.1. Table 4-1 listed the groundwater reference levels. The tables provided in Appendix A list the values of the RI criteria for each analyte. Detected concentrations of an analyte at or above one or more of the RI criteria are highlighted in yellow.

Based on the data presented in Appendix A, two chlorinated VOCs (i.e., chloroform and 1,1,2,2-tetrachloroethane) and three pesticide compounds (i.e., alpha-BHC, heptachlor, and heptachlor epoxide) were detected above criteria in the Northern Bush River Area. Three monitoring wells (i.e., WBR-76, WBR-84, and WBR-74) contained detected concentrations of chloroform above RBCs for tap water for only one round of sampling. Wells WBR-81 and WBR-82 contained detected concentrations of 1,1,2,2-tetrachlorethane above RBCs for tap water during one round of sampling. Only one monitoring well contained detected concentrations of a chlorinated VOC above criteria for two consecutive rounds of sampling. Well WBR-11 contained detected concentrations of chloroform above RBCs for tap water at 4 µg/L during both rounds of sampling. Wells WBR-11, WBR-87, and WBR-88 contained detected concentrations of the pesticide heptachlor above RBCs during the first round of sampling. Heptachlor epoxide was detected above RBCs in well WBR-80 during the second round of sampling. Only the pesticide alpha-BHC was detected in one well over consecutive rounds of sampling. Groundwater samples from monitoring well WBR-88 contained detected concentrations of alpha-BHC at 0.03 µg/L (i.e., above RBCs) and 0.006 µg/L (i.e., below RBCs). No organic compounds were detected above RBCs in the remaining ten Northern Bush River Area monitoring wells (i.e., WBR-12, -13, 15, -83, -86, -70, -75, -77, -78, and –79).

Groundwater samples from five monitoring wells contained detected concentrations of one or more inorganic analytes above both the RBCs for tap water and upper reference limits over two consecutive rounds. Wells WBR-15, WBR-77, and WBR-78 contained detected concentrations of iron exceeding both criteria for two rounds of groundwater sampling. Manganese exceeding criteria was detected in two rounds of groundwater samples from wells WBR-75, WBR-77, and WBR-82. Well WBR-75 also contained detected concentrations of arsenic exceeding criteria for both rounds of sampling. Over two rounds of sampling, four monitoring wells contained detected concentrations of one or more inorganic analytes exceeding only the upper reference limit. Two rounds of groundwater samples from well WBR-12 contained iron concentrations exceeding reference levels. Well WBR-77 contained barium concentrations exceeding reference samples over two rounds. Cobalt was detected above reference levels in two rounds of groundwater samples from well WBR-83. Well WBR-82 contained detected concentrations of aluminum, beryllium, calcium, cobalt, magnesium, nickel, sodium, and zinc exceeding upper

reference limits in two rounds of groundwater sampling. Wells WBR-78 and WBR-80 contained detected concentrations of arsenic exceeding only RBCs over consecutive rounds of sampling.

Two monitoring wells (i.e., WBR-74 and WBR-75) contained detected concentrations of radionuclides exceeding reference limits. Well WBR-74 contained gross beta detections exceeding the upper reference limit during the first round of sampling. Well WBR-75 also contained gross beta detections exceeding the upper reference limit during the second round of sampling. None of the Northern Bush River monitoring wells contained gross alpha concentrations exceeding criteria.

4.5.2 Results of Surface Water and Sediment Sampling

The surface water and sediment investigation consisted of two rounds of surface water sampling and one round of sediment sampling from 13 points. Figure 4-2 depicted the surface water and sediment sampling locations. All sediment samples screened negative for the presence of chemical warfare agents. Tables presenting the detected compounds for both rounds of surface water and one round of sediment are provided in Appendix B.

All detections of organic and inorganic compounds were screened against selected RI comparison criteria outlined in Section 4.4.1. Table 4-2 and Table 4-3 listed the seasonal surface water and sediment reference levels, respectively. The tables provided in Appendix B list the values of the RI criteria for each analyte. Detected concentrations of an analyte at or above one or more of the RI criteria are highlighted in yellow.

Based on the two rounds of surface water data presented in Appendix B, three VOCs (i.e., chloroform, chloromethane, and 1,1,2,2-tetrachloroethane) and one SVOC (i.e., di-n-butyl phthalate) were detected above criteria in the Northern Bush River Area. None of the detections of organic compounds exceeded both recreational water RBCs and ecological screening criteria. Surface water location C35-SW-01 contained detected concentrations of 1,1,2,2-tetrachloroethane exceeding recreational water RBCs water during the first round of sampling. Chloromethane was detected exceeding recreational water RBCs during the second round of sampling at C36-SW-02. Only samples from one surface water location contained detected concentrations of a chlorinated VOC above criteria for two consecutive rounds of sampling. Location C7-SW-05 contained detected concentrations of chloroform above recreational RBCs criteria during rounds one and two at 3 µg/L and 6 µg/L, respectively. Five surface water sampling locations (i.e., C7-SW-01, C35-SW-01, C35-SW-02, C36-SW-01, and C36-SW-02)

contained detected concentrations of di-n-butyl phthalate exceeding ecological screening criteria during one round of sampling.

Based on the one round of sediment sampling results presented in Appendix B, the pesticide 4,4'-DDT and related isomers 4,4'-DDE and 4,4'-DDD were detected above RI screening criteria in the Northern Bush River Area. One or more of the DDTr compounds were detected exceeding ecological screening criteria and/or upper reference limits at sediment sampling locations C7-SD-04, C7-SD-03, C35-SD-02, C36-SD-02, and C36-SD-04. 4,4'-DDD and 4,4'-DDE were detected at concentrations exceeding ecological screening criteria and upper reference limits at sediment locations C7-SD-04, C7-SD-03, and C35-SD-02. The pesticide 4,4'-DDT was detected at C7-SD-03 exceeding ecological screening criteria and at C35-SD-02 exceeding ecological criteria and upper reference limit. Only sediment samples from location C35-SD-02 contained detected concentrations of all three DDTr compounds exceeding both ecological criteria and upper reference limits.

Six inorganic analytes (i.e., aluminum, arsenic, cadmium, iron, lead, and mercury) were detected above criteria in one or more of the 13 surface water sampling locations. Two inorganic analytes (i.e., aluminum and iron) were detected above criteria over consecutive rounds of surface water sampling. Aluminum was detected exceeding ecological screening criteria during both rounds of sampling at 12 of the 13 surface water sampling locations. Location C36-SW-04 contained detected concentrations of aluminum exceeding ecological criteria only during the first round of sampling. Surface water samples from C7-SW-03, C7-SW-04, C35-SW-02, C35-SW-03, C36-SW-01, C36-SW-02, and C36-SW-03 contained detected concentrations of iron exceeding ecological screening criteria for both rounds of sampling. None of the detected concentrations of aluminum or iron exceeded their respective upper reference limits. Detected arsenic concentrations in first round surface water samples from C7-SW-02, C7-SW-03, and C7-SW-04 exceeded recreational water RBCs. Second round surface water samples from C36-SW-03 contained detected concentrations of arsenic above recreational water RBCs and the upper reference limit. Cadmium was detected above ecological screening criteria and the upper reference limit in second round surface water samples from C36-SW-02. First round lead detections exceeded ecological screening criteria in C35-SW-03, C35-SW-04, and C36-SW-04, and exceeded ecological criteria and the upper reference limit in C35-SW-01. In addition, second round surface water samples from C35-SW-04 and C36-SW-03 contained detected concentrations of mercury exceeding ecological screening criteria and the upper reference limit.

Six inorganic analytes (i.e., arsenic, chromium, mercury, selenium, silver, and zinc) were detected above criteria in one or more of the 13 sediment sampling locations. Detected

concentrations of chromium ranging from 5.1 mg/kg to 26.4 mg/kg exceeded ecological screening criteria at all 13 sediment sampling locations. Sediment sampling locations C7-SD-04 and C7-SD-05 contained detected concentrations of zinc exceeding ecological screening criteria. Detected concentrations of mercury in sediment from C36-SD-04 exceeded ecological screening criteria. Arsenic was detected in sediment from C7-SD-04 exceeding recreational sediment RBCs. All detections of arsenic, chromium, mercury, and zinc were below their respective upper reference limits. Sediment samples from C7-SD-04 contained detected concentrations of selenium exceeding the upper reference limit, and silver exceeding the upper reference limit and ecological screening criteria.

Reference values and screening criteria are not available for radionuclides in surface water. Two rounds of gross alpha and gross beta detections in surface water ranged from non-detected to 10 pCi/g and non-detected to 26 pCi/g, respectively. The sediment sample from C35-SD-04 contained gross beta detections at 19.9 pCi/g exceeding the upper reference limit. The naturally occurring radionuclide potassium-40 was detected in four out of the five sediment samples in Cluster 7. Detected concentrations of potassium-40 ranged from 3.55 pCi/g to 44.8 pCi/g, exceeding the recreational sediment RBC of 0.72 pCi/g.

4.5.3 Results of Surface Soil Sampling

The surface soil investigation consisted of one round of sampling from 30 locations in the Northern Bush River Area. Figure 4-3 depicted the surface soil sampling locations. All surface soil samples screened negative for the presence of chemical warfare agents. Tables presenting the detected compounds from surface soil sampling are provided in Appendix C.

All detections of organic and inorganic compounds were screened against selected RI comparison criteria outlined in Section 4.4.1. Table 4-4 listed the surface soil reference limits. The tables provided in Appendix C list the values of the RI criteria for each analyte. Detected concentrations of an analyte at or above one or more of the RI criteria are highlighted in yellow.

Based on the one round of surface soil analytical results presented in Appendix B, the pesticide 4,4'-DDT and related isomers 4,4'-DDE and 4,4'-DDD were detected above RI screening criteria in the Northern Bush River Area. In addition, eight PAHs were detected above RI screening criteria. One or more of the DDTr compounds were detected above one or more of the RI criteria in samples from 18 surface soil locations. Only one surface soil sampling location (i.e., C35-SS-12) contained detected concentrations of all three DDTr compounds above ecological screening criteria and the upper reference limit. One or more PAHs were detected above criteria at four

surface soil sampling locations in Cluster 36. Soil samples from C36-SS-04 contained detected concentrations of seven PAHs (e.g., benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, fluoranthene, and pyrene) exceeding ecological screening criteria. One PAH benzo(a)pyrene was detected above residential soil RBCs at C36-SS-04 and C36-SS-12. None of the detected PAHs in surface soil exceeded their respective upper reference limits.

Seven inorganic analytes (i.e., arsenic, beryllium, copper, manganese, mercury, nickel, and silver) were detected above criteria and their respective upper reference limits in one or more of 15 surface soil locations. Detected concentrations of arsenic ranging from 7 mg/kg to 32.5 mg/kg exceeded residential soil RBCs and upper reference limits at C35-SS-07, C35-SS-08, C35-SS-14, and C36-SS-04. One soil sampling location C36-SS-01 contained detected concentrations of beryllium at 1.7 mg/kg, exceeding ecological criteria and reference limits. Surface soil locations C7-SS-04, C36-SS-01, and C36-SS-12 contained detected concentrations of copper ranging from 26.7 mg/kg to 43.4 mg/kg, exceeding ecological screening criteria and reference limits. Concentrations of mercury ranging from 0.08 mg/kg to 0.32 mg/kg were detected at eleven soil sampling locations, exceeding ecological screening criteria and reference limits. Nickel was detected in surface soil exceeding ecological criteria and upper reference limits from C7-SS-04, C35-SS-08, and C36-SS-01 at 25.1 mg/kg, 63.9 mg/kg, and 30.2 mg/kg, respectively. Surface soil location C36-SS-12 contained detected concentrations of silver at 1.4 mg/kg, exceeding ecological criteria and reference limits. Only manganese detected in surface soil from C36-SS-06 at 2,460 mg/kg exceeded ecological screening criteria, residential soil RBCs, and upper reference limits. Surface soil sampling location C36-SS-01 contained detected concentrations of the most inorganic analytes exceeding criteria (i.e., beryllium, copper, mercury, and nickel).

Three surface soil locations C63-SS-03 through C36-SS-05 contained detected concentrations of both gross alpha and gross beta exceeding their respective upper reference limits. Two surface soil locations C35-SS-03 and C35-SS-04 also contained detected gross beta concentrations exceeding the upper reference limit. Three surface soil locations C7-SS-04, C7-SS-06, and C7-SS-15 contained detected concentrations of the radionuclide potassium-40 ranging from 15.6 pCi/g to 45.9 pCi/g.

4.5.4 Results of Subsurface Soil Sampling

The subsurface soil investigation consisted of one round of sampling from eight locations in Cluster 7. Figure 4-3 also depicted the subsurface soil sampling locations. All subsurface soil

samples screened negative for the presence of chemical warfare agents. Tables presenting the detected compounds from the subsurface soil sampling are provided in Appendix D.

All detections of organic and inorganic compounds were screened against selected RI comparison criteria outlined in Section 4.4.1. Reference limits do not specifically exist for the subsurface soil media. However, detected analytes in subsurface soil samples were compared to surface soil reference limits provided in Table 4-4. The analytical results tables provided in Appendix D list the values of the RI criteria for each analyte. Detected concentrations of an analyte at or above one or more of the RI comparison criteria are highlighted in yellow.

Based on the tables provided in Appendix D, the pesticide degradation products 4,4'-DDE and 4,4'-DDD, and 18 PAHs were detected above RI screening criteria in Cluster 7 subsurface soil. 4,4'-DDD was detected in five subsurface soil samples exceeding only the upper reference limit. Subsurface soil sample C7-SO-11 contained detected concentrations of 4,4'-DDE above the ecological screening criteria, but below upper reference limits. Subsurface soil samples C7-SO-03 and C7-SO-11 contained detected concentrations of 18 PAHs and 10 PAHs exceeding criteria, respectively. Subsurface soil from C7-SO-03 contained detected concentrations of five PAHs (i.e., benzo(a) anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene) exceeding ecological screening criteria, residential soil RBCs, and upper reference limits. Of the 18 detected PAHs at C7-SO-03, 16 PAHs were detected exceeding the upper reference limits. The detected concentrations of the PAHs exceeding criteria at C7-SO-03 ranged from the lowest 2-methylnaphthalene at 150 µg/kg to the highest pyrene at 6,400 µg/kg. Of the 10 detect PAHs at C7-SO-11, four PAHs were detected above ecological screening criteria and the upper reference limits.

Eleven inorganic analytes (i.e., aluminum, arsenic, chromium, copper, lead, iron, nickel, mercury, thallium, vanadium, and zinc) were detected above RI criteria in one or more of the Cluster 7 subsurface soil samples. Eight inorganic analytes aluminum, arsenic, chromium, lead, iron, nickel, vanadium, and zinc were detected above ecological screening criteria, but below upper reference limits, in all eight subsurface soil samples. Detected concentrations of arsenic ranging from 6.6 mg/kg to 7.4 mg/kg exceeded residential soil RBCs and upper reference limits at C7-SO-01, C7-SO-03, and C7-SO-11. Two subsurface soil sampling locations C7-SO-03 and C7-SO-11 contained detected concentrations of copper exceeding ecological criteria and reference limits. Mercury was detected at 0.25 mg/kg and 0.07 mg/kg in subsurface soil samples from C7-SO-08 and C7-SO-11, respectively, exceeding ecological criteria and upper reference limits. Nickel was detected in subsurface soil exceeding ecological criteria and upper reference limits from C7-SO-03 at 50.8 mg/kg and C7-SO-11 at 24.8 mg/kg. Subsurface soil location C7-

SO-08 contained detected concentrations of silver at 1.9 mg/kg, exceeding ecological criteria and reference limits. Thallium ranging in concentrations from 0.58 to 2.1 mg/kg was detected at four subsurface soil locations, exceeding ecological criteria and reference limits. Only iron detected in subsurface soil from C7-SO-01 at 25,500 mg/kg exceeded ecological screening criteria, residential soil RBCs, and upper reference limits. Subsurface soil sampling location C7-SO-03 contained detected concentrations of the most inorganic analytes, exceeding criteria (i.e., arsenic, copper, nickel, and thallium).

The radionuclide potassium-40 was detected in four subsurface soil samples, exceeding the upper reference limit. Subsurface soil from C7-SO-02, C7-SO-03, C7-SO-10, and C7-SO-11 had detected concentrations of potassium-40 at 48.7 pCi/g, 47.4 pCi/g, 48.7 pCi/g, and 42.7 pCi/g, respectively.

4.5.5 Results of Sludge Sampling

The sludge investigation consisted of one round of sampling from a septic tank associated with Building E2169 and from the wastewater package treatment plant at the former Bio-Sensor Research Facility (Site 27). Figure 4-3 depicted the sludge sampling locations. Tables presenting the compounds from the sludge sampling are provided in Appendix E.

All detections of organic and inorganic compounds in sludge were screened against selected RI comparison criteria outlined in Section 4.4.1. Reference limits do not specifically exist for the sludge. Since both sludge samples were sampled as a water media, detected analytes were compared to the surface water reference limits provided in Table 4-3. The analytical results tables provided in Appendix E list the values of the RI criteria for each analyte. Detected concentrations of an analyte at or above one or more of the RI comparison criteria are highlighted in yellow.

No organic compounds were detected in the sludge sample from C7-SL-09. The two pesticide degradation compounds 4,4'-DDD and 4,4'-DDE, one phalate, six PAHs, and one miscellaneous semivolatile n-nitrosodiphenylamine were detected above RI criteria in sludge from C36-SL-11. Detections of 4,4'-DDD and 4,4'-DDE exceeded the human health screening criteria. 4.4'-DDD concentrations exceeded the ecological screening criteria. Di-n-butyl phthalate was detected at 6 µg/L, exceeding ecological screening criteria. Detected concentrations of the six PAHs acenaphthene, benzo(k)fluoranthene, dibenzofuran, fluorene, naphthalene, and phenanthrene occurred. In addition, n-nitrosodiphenylamine was detected at 4 µg/L, exceeding the listed human health criteria.

Sludge sample C7-SL-09 contained detected concentrations of five inorganic analytes, exceeding RI criteria. Detected concentrations of three inorganic analytes aluminum, copper, and iron exceeded only ecological screening criteria in C7-SL-09. The sludge sample from C7-SL-09 also contained detected concentrations of silver and zinc, exceeding ecological criteria and upper reference limits.

A total of 13 inorganics were detected above RI criteria in sludge sample C36-SL-11. Lead was detected at concentrations that exceeded human health criteria, ecological criteria, and upper reference limits. Detected concentrations of cadmium, copper, iron, mercury, zinc, and cyanide exceeded both ecological screening criteria and upper reference limits. Concentrations of antimony, barium, beryllium, chromium, and vanadium detected in sludge sample C36-SL-11 exceeded only the upper reference limits, and aluminum exceeded ecological criteria.

4.5.6 Soil Gas Survey Results

The passive soil gas survey results show the relative intensities by ion count levels of three VOC groupings (i.e., chloroform, BTEX, and diesel range alkanes) from sorbers placed at three Gravel and Soil Storage localities (Site 22), Building E2144, the area between Buildings E2150 and E2148, the doorways of warehouses at the Warehouse Storage Areas (Site 19), the Drummed Soil Road Barricade Site (Site 26A), and at Building 846 (E2194) Waste Disposal Site (Site 24). Figure 2-4 depicted the soil gas survey locations.

Results northeast of Building 846 (E2194) Waste Disposal Site (Site 24) contained BTEX with concentrations ranging up to 6.01 µg. Diesel range alkanes (i.e., undecane, tridecane, and pentadecane) and trimethylbenzenes are present at concentrations ranging up to 1.03 µg. Chloroform was non-detected in the Building E2194 survey.

BTEX compounds were detected at concentrations ranging up to 1.92 µg at the three Gravel and Soil Storage localities (Sites 22A, 22B, and 22C). Diesel range alkanes are at low levels, from non-detected to 4.28 µg within the Building E2144 grid. Chloroform was only detected in two modules within the Cluster 35 soil gas grids.

Trace levels of BTEX, diesel range alkanes, and trimethylbenzenes are in soil gas near the doors of the buildings at the Warehouse Storage Area (Site 19). Trimethylbenzenes range up to 0.66 µg at Buildings E2196, E2162, and E2160. Diesel range alkanes were detected up to 0.65 µg at Buildings E2196, E2168, E2162, and E2160. BTEX range up to 0.62 µg at Buildings E2196, E2198, E2168, E2166, and E2160. Chloroform was detected in soil gas outside Building E2198 at 10.09 µg, and outside Building E2196 at 6.14 µg.

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5.0 CONTAMINANT FATE AND TRANSPORT

This section addresses the persistence and migration characteristics of contaminants discussed in Section 4.5, Summary of Sampling Results. These detected compounds are at or above listed RI comparison criteria for the sampled environmental media. The identified contaminants could not be attributed to cross contamination or difficulties with the analytical method.

Northern Bush River sampling results do not indicate any significant sustained patterns of contamination; therefore, compounds selected for evaluation are those which are atypical for the area, are of interest to the risk assessment, and which indicate a potential impact. Contaminant fate and transport are based on the nature of the contaminants detected, physical characteristics of the sites, and source characteristics.

5.1 Potential Routes of Migration

The primary route of migration for the Northern Bush River area is contaminant release to the soil, infiltration of contamination through the vadose zone to the surficial aquifer groundwater. Subsequent groundwater migration causes the contaminants to move toward the tributaries of Lauderick Creek and Kings Creek. Groundwater then discharges into these surface water bodies.

The secondary route of migration is water runoff causing erosion of contaminated soil and/or sediment, and transport into nearby drainage streams, marshes, and surface water bodies. Surface water drainage is primarily toward tributaries of Lauderick Creek or Kings Creek. Contaminated sediment particles can be suspended in surface water for further transport or deposition downgradient in the creeks, and eventually entering the Bush River.

5.2 Contaminant Persistence

This section generally summarizes the environmental fate of contaminants identified as potential impacts to the Northern Bush River area sites. All the analytes and compounds detected within each media fall within the general groupings of SVOCs, pesticides, metals, or military-unique compounds.

PAHs were the primary SVOCs detected in the Northern Bush River environmental media. One or more of 18 PAHs have been detected above RI criteria.. Surface and subsurface soil in the Northern Bush River area have detected concentrations of acenaphthene, anthracene, benzo(a)anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, carbazole, chrysene, dibenzofuran, dibenz[a,h]anthracene, fluoranthene,

fluorene, indeno[1,2,3-cd]pyrene, 2-methylnaphthalene, naphthalene, phenanthrene, and pyrene. PAHs are a group of chemicals that are associated with incomplete combustion of organic substances such as wood and petroleum products. Most PAHs occur naturally and tend to be persistent in the environment. The PAHs found in the Northern Bush River media sampling are all considered high molecular weight compounds (228-278 grams per mol), and can be expected to have similar fate and transport properties. PAHs tend to have low water solubilities. In oxygenated environments, PAHs can be reduced through microbial metabolism. In soil, PAHs tend to degrade because of microbial metabolism. The rate of degradation is dependent upon factors such as temperature, pH, oxygen availability, soil type, other contaminants present, and PAH concentrations (Agency for Toxic Substances and Disease Registry [ATSDR], 1995).

The primary pesticide impacting the Northern Bush River area is 4,4'-DDT and related isomers ,4'-DDE, and 4,4'-DDD. These DDTr compounds are fairly resistant to destruction by light and oxidation and, therefore, persist in the environmental media. Under aerobic conditions, 4,4'-DDT is known to degrade into 4,4'-DDE by dehydrochlorination. Under anaerobic conditions, 4,4'-DDT transforms into 4,4'-DDE by reductive dechlorination. Over time, the ratio of 4,4'-DDE to 4,4'DDT is expected to increase due to the degradation process. Both 4,4'-DDE and 4,4'-DDD are extremely resistant to further degradation. All three compounds are only slightly soluble in water and, over extended periods of time, 4,4'-DDT, 4,4'-DDE and 4,4'-DDD compounds undergo extensive adsorption to soil and sediment particles. This strong tendency to adsorb to soil particles also creates a prolonged existence in the soil and sediment media. The DDTr compounds could enter the surface water media through secondary route of migration from areas of contaminated soil. When these pesticides are released into the surface water, they absorb strongly to both suspended and bottom sediments. Pesticides in general do not readily leach into the groundwater media unless a significant concentration is released into the soil. (ATSDR, 1988a).

The inorganic compound arsenic was detected above criteria in groundwater, surface water, surface soil, and subsurface soil. Arsenic is usually found in the environment combined with one or more other elements. These combinations can result in either organic or inorganic forms. Transport of arsenic compounds are generally due to erosion of particles, including soil and sediment containing clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material to which arsenic adsorbs. Migration and partitioning of arsenic in water is dependent upon the chemical form of the arsenic and other analytes present. Arsenic can bioconcentrate in aquatic organisms, but does not appear to have a tendency to biomagnify. In both water and soil, arsenic transformations are dependent on factors such as the oxidation-reduction potential, pH, temperature, salinity, and the presence of biota and can occur in several ways, including oxidation-reduction reactions, ligand exchange, and biotransformation (ATSDR, 1997).

Lead is retained strongly in soil and sediment media. Once introduced to the soil or sediment, lead forms a relatively stable organic-metal complex or chelates with soil organic matter. Lead can also adsorb or attach to minerals located within the soil by way of chemical reactions. Once transformed by soil organics or minerals contained in the soil, lead becomes a very persistent environmental contaminant. Most of these lead compounds are resistant to oxidation and biodegradation. Only lead sulfate is relatively soluble and can leach through the soil to the groundwater. Vegetation removes lead from the soil, then lead is returned to the soil when the contaminated vegetation begins to decay (ATSDR, 1988b).

Mercury can exist in mercuric and mercurous states in surface water and soil, which influences its transport and partitioning. Sorption of mercury is dependent on the organic content of the soil or sediment. Erosion and runoff is an important mechanism for the migration of mercury because of its tendency to sorb onto organic particles. Mercury tends to undergo biotransformation in surface water and soil, and becomes a methylmercuric ion under favorable conditions. Mercuric mercury can also be transformed to metallic mercury by oxidation-reduction and photolysis. It is also a naturally occurring element found in the environment in various forms, such as organic mercury, inorganic mercury, and as the elemental metal. When found in environmental media, mercury has three valence states that are dependent on oxidation-reduction potential and pH (ATSDR, 1993).

TCPU, a military clothing impregnate degradation product, was detected in one surface soil sample, C07-SS-15, and in one subsurface soil sample, C07-SO-03. There are currently no screening criteria for TCPU. TCPU has an extremely low solubility, is stable, immobile, and persistent in the aqueous environment. Persistence of TCPU in an aquatic environment is effected by its octanol-water partition coefficient. TCPU has a partition coefficient greater than 5, indicating that this compound likely resists both chemical and biological alteration. Although TCPU binds to sediment, the potential exists for benthic organisms to bioaccumulate this hydrophobic compound directly from the sediment (USAEHA, 1989; Harvey et al., 1990).

5.3 Contaminant Migration

This section is generally used to describe the patterned similar-media or cross-media migration of contaminants identified within a study area. Analysis of environmental media sampling results for the Northern Bush River area does not show direct correlations between detected contaminants across multiple media. The majority of all the contaminants identified in the Northern Bush River area appear to be isolated and localized impacts. The PAHs, DDTr compounds, TCPU, and the inorganic analytes discussed in the previous section are fairly immobile contaminants, once released into the environment. Therefore, these contaminants primarily follow the secondary route of migration identified in Section 5.1.

6.0 Baseline Risk Assessment